Status of Nuclear Safety Research and Development Work Tasks at ORNL

Douglas G. Bowen
Nuclear Data and Criticality Safety Group Leader
Reactor and Nuclear Systems Division
Oak Ridge National Laboratory

EFCOG/NFS Meeting
Sandia National Laboratory

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Agenda

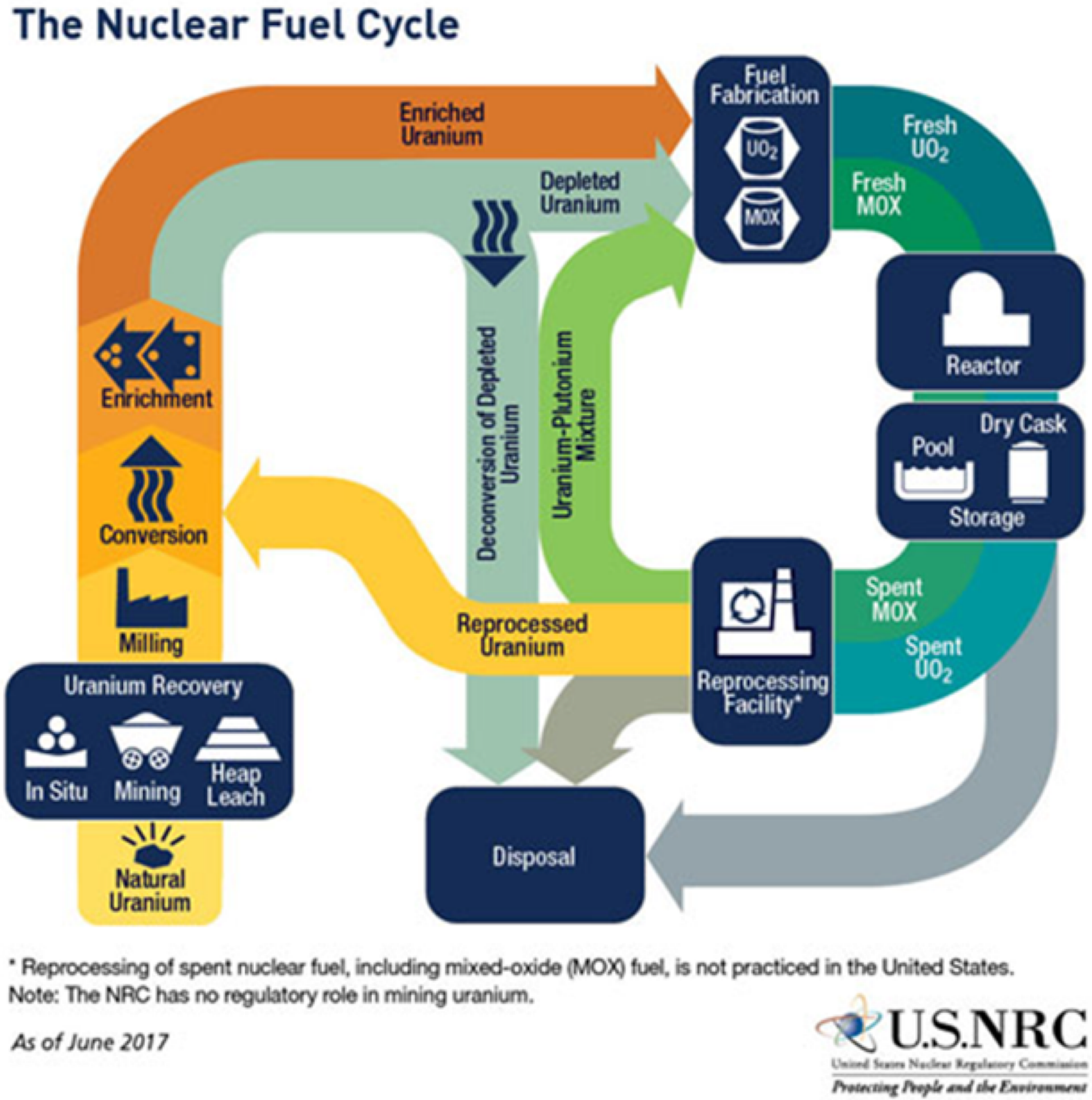
- Provide a status update for NSR&D tasks in progress at ORNL
  - **2017**
    - 17.?? – Workshop on Measurement of Fissionable Material Holdup (ORNL)
    - 17.18 – Upgrade Holdup Monitoring System (SNAPSHOP) to support *in situ* nondestructive assay measurements of fissionable materials (ORNL)
    - 17.19 – Technical Support for DNFSB Recommendation 2007-1 and NNSA Nondestructive Assay Technical Infrastructure Program (ORNL, Y-12, SRS)
  - **2018**
    - 18.03 – Verification of Subcritical Limits in ANSI/ANS-8.1-2014 for Nuclear Facility Safety Use (ORNL)
    - 18.19 – Gamma Imaging for In-Situ Holdup (ORNL, Y-12)
    - 18.20 – Drone Assisted Dispersion and Dose Consequence Modeling using MACCS2 in the DOE Complex (ORNL)

17.?? – Workshop on Measurement of Fissionable Material Holdup

ORNL POC: Angela Lousteau (ORNL)

Nondestructive Assay

- NDA encompasses a suite of nuclear material measurement techniques crucial to assuring effective, efficient, safe, and secure nuclear operations in the US and around the globe
- Applications in diverse programmatic areas:
  - Decontamination and decommissioning
  - Waste management
  - Nuclear criticality safety
  - Material control and accounting



Sustainability and advancement of domestic NDA capabilities

- DNFSB Recommendation 2007-1 identified the need for improved coordination in managing NDA challenges across the DOE complex
- Would a coordinated, national NDA technical support program provide significant benefits to safety, security, operations, and mission effectiveness of US nuclear operations?

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Workshop Outcomes

- Conclusion
  - A coordinated, national NDA Program is needed to nurture collaborative information exchange, ensure knowledge preservation, and address the many technical and operation NDA challenges of the US DOE
  - A strategic program will not only help sustain current NDA capabilities to support ongoing nuclear operations, but support advancements and new development in NDA to facilitate evolving needs and challenges facing national programs

Key NDA challenges facing the US DOE

- Lack of information sharing, knowledge management, and adequate resource availability
- Large measurement uncertainties that are difficult to quantify
- Decaying or obsolete technology with little support for R&D or technology development
- Lack of data management infrastructure
- View of NDA as a cost to be minimized rather than an asset to be treasured

Programmatic needs/recommendations for a sustainable NDA capability in the US

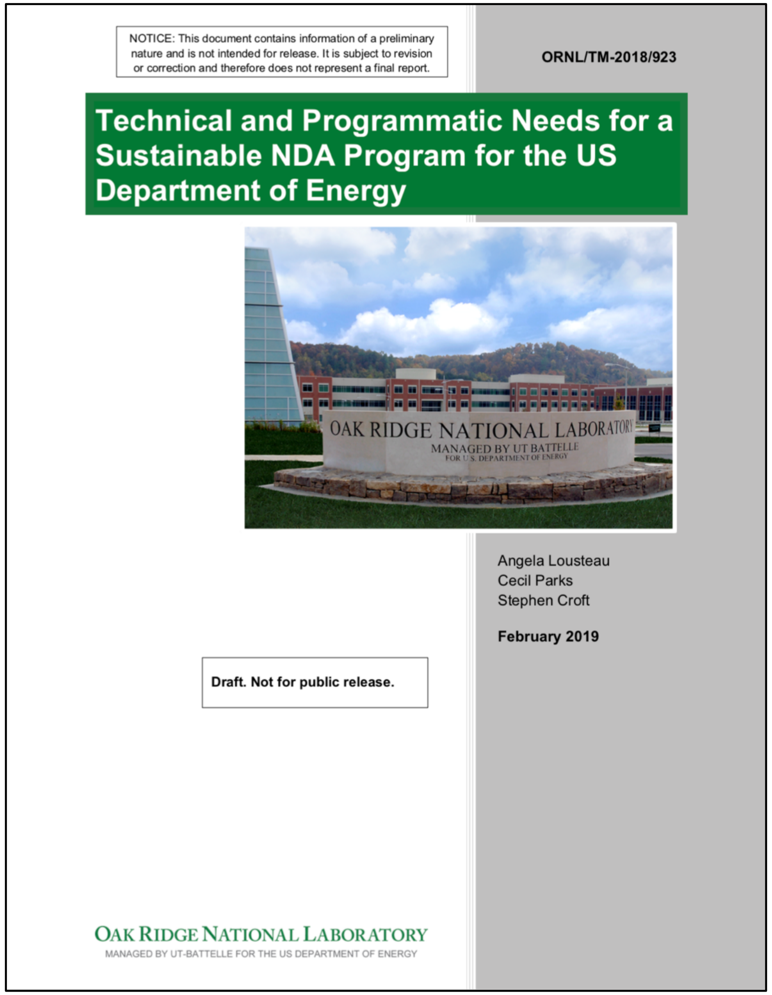
- Formation of a technical steering committee to provide guidance and coordination for NDA technology development to:
  - Reduce the fragmented site-by-site approach
  - Modernize capability consistently
- Development of a knowledge management process/tool to enable information and resource sharing
- Increased emphasis on technical training and professional development opportunities to support staff development and succession planning
- Standardization of the qualification and acceptance process for NDA equipment/methods
- Expand DOE directives related to NDA measurements to encourage consistent practices across the DOE complex

Technical needs/recommendations for a sustainable NDA capability in the US

- Focused efforts to sustain NDA hardware/software compatibility with constantly evolving computer systems
- Increased availability of reference nuclear materials for calibration and testing of new NDA systems/techniques
- Increased access to nuclear facilities and resources to support advancements in hardware and software development
- Focused R&D efforts on active NDA systems/techniques using portable neutron generators that could eliminate the need for radiation sources

Next Steps

- Determine the DOE HQ champions to sponsor this program long term for all NDA end users
- Assemble NDA steering committee to:
  - Develop or define a clear and sustainable mission and vision for a national-level NDA Program
  - Provide guidance and support for nationally recognized training courses and qualifications for NDA practitioners
  - Administer a domestic technology development program and/or a technical assistance program (like the TSG)
- Sustain an NDA website to serve as a data repository for relevant NDA resources (https://nda.llnl.gov)
- Increase support for consensus standard writing committees such that relevant standards can be strengthened
- Sponsor annual technical meetings and workshops on topics such as in situ holdup, isotopic analyses, and modeling and simulation of NDA techniques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ORNL/TM-2018/923

Technical and Programmatic Needs for a Sustainable NDA Program for the US Department of Energy

Angela Lousteau
Cecil Parks
Stephen Croft

February 2019

Draft. Not for public release.

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17.18 – In situ Nondestructive Assay (NDA) – SNAPSHOT Project

ORNL POC: Angela Lousteau (ORNL)

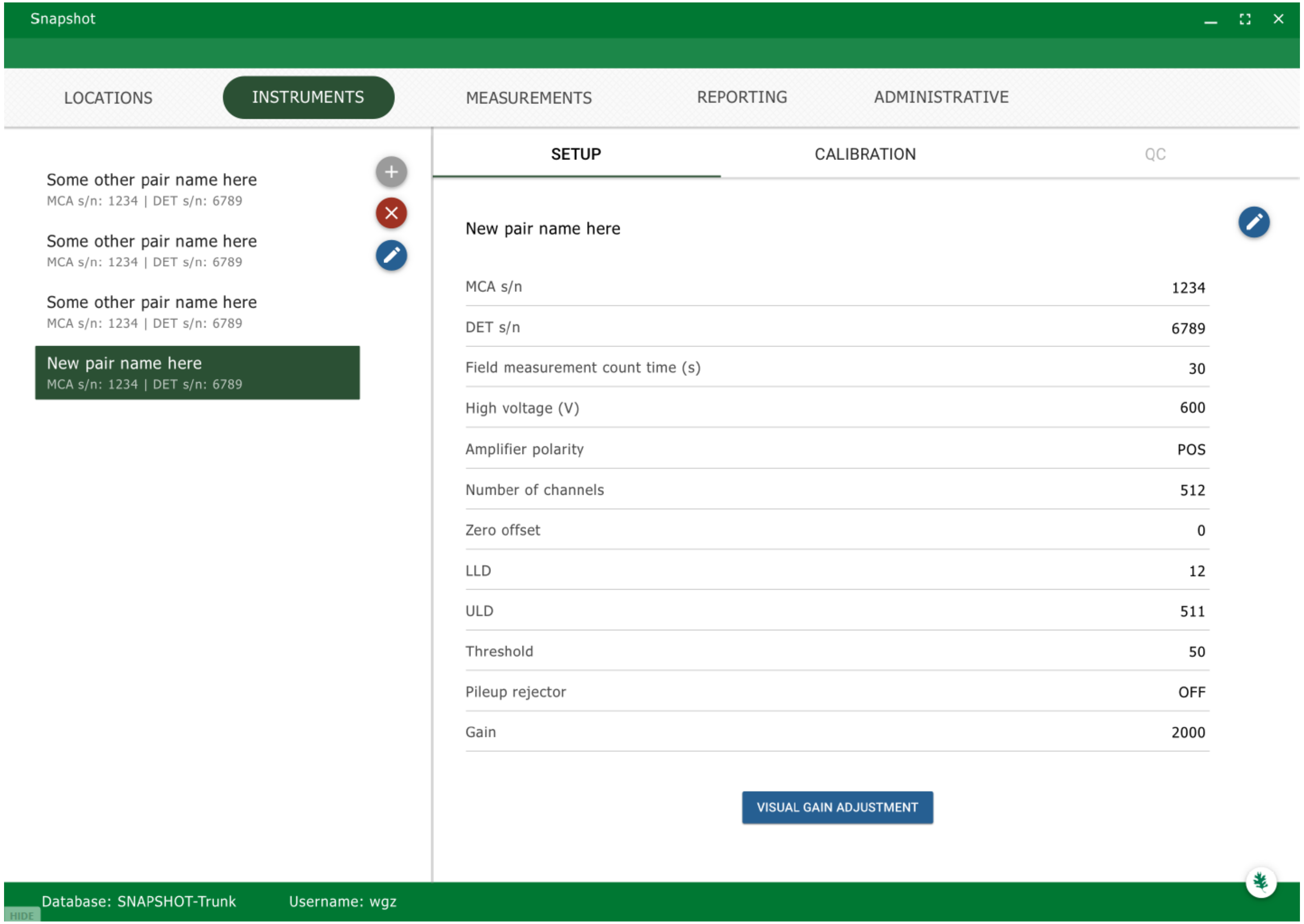
SNAPSHOT – Background

- Objective: Develop a modern, long term sustainable Holdup Measurement System for supporting *in situ* NDA measurements at processing facilities
- Previous sprint included the ability to assign average groups to a defined set of measurement points mirroring the capability in the existing HMS-4 software
- This concluded the Measurement setup and Analysis feature development → Snapshot can now be used to analyze measurement data collected with HMS-4 systems

SNAPSHOT – Current tasks

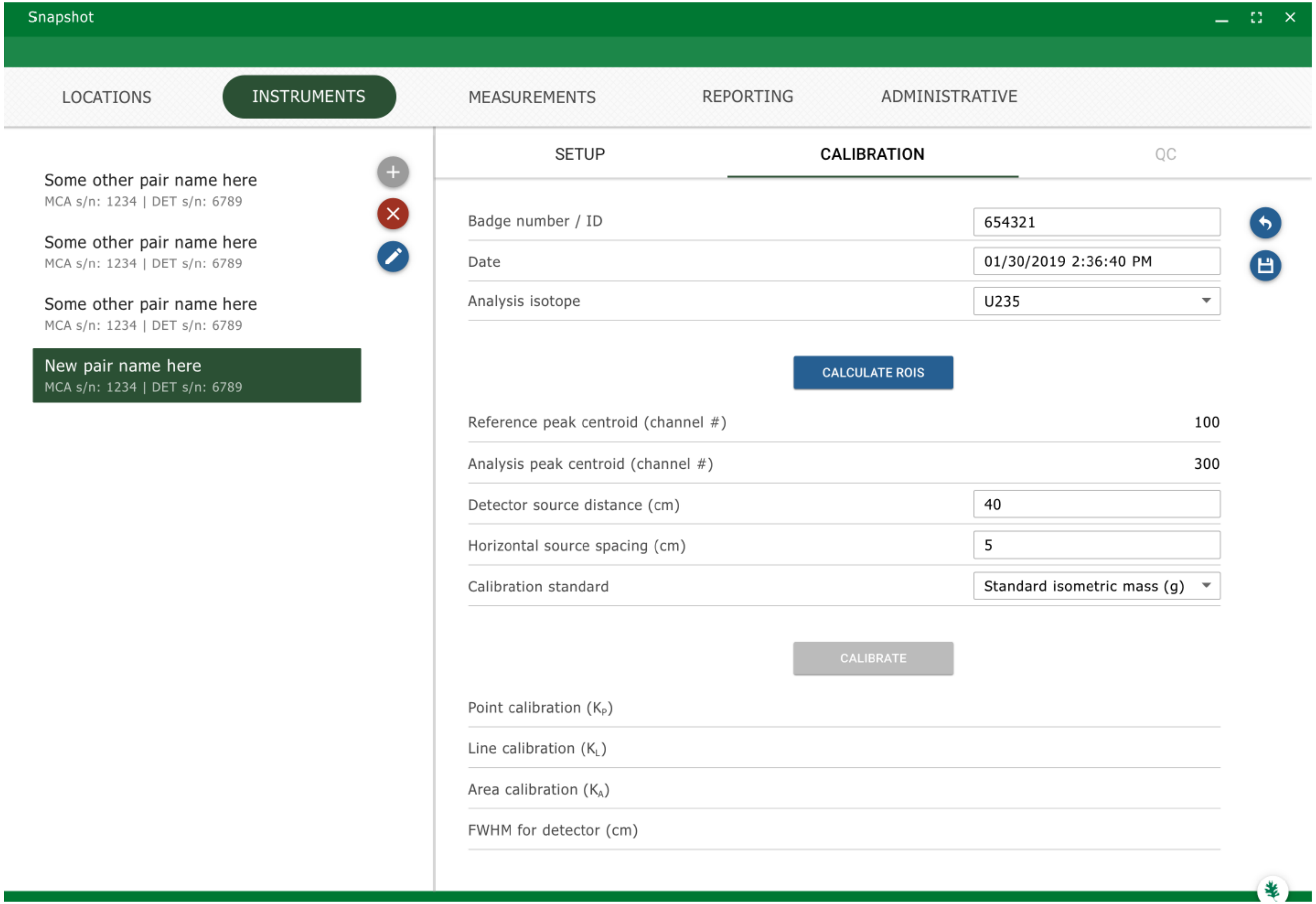
- Current task includes development of the *Instruments* tab
  - *Setup* subtab where users setup the detector and MCA parameters
  - *Calibration* where users perform measurements to determine the calibration constants necessary for analysis
  - QC subtab where users establish QC parameters related to both the reference source and the check source
- This task involves hardware integration since SNAPSHOT will pull setup and measurement data from the MCA directly, eliminating the need to manually enter calibration parameters

Instruments - Setup



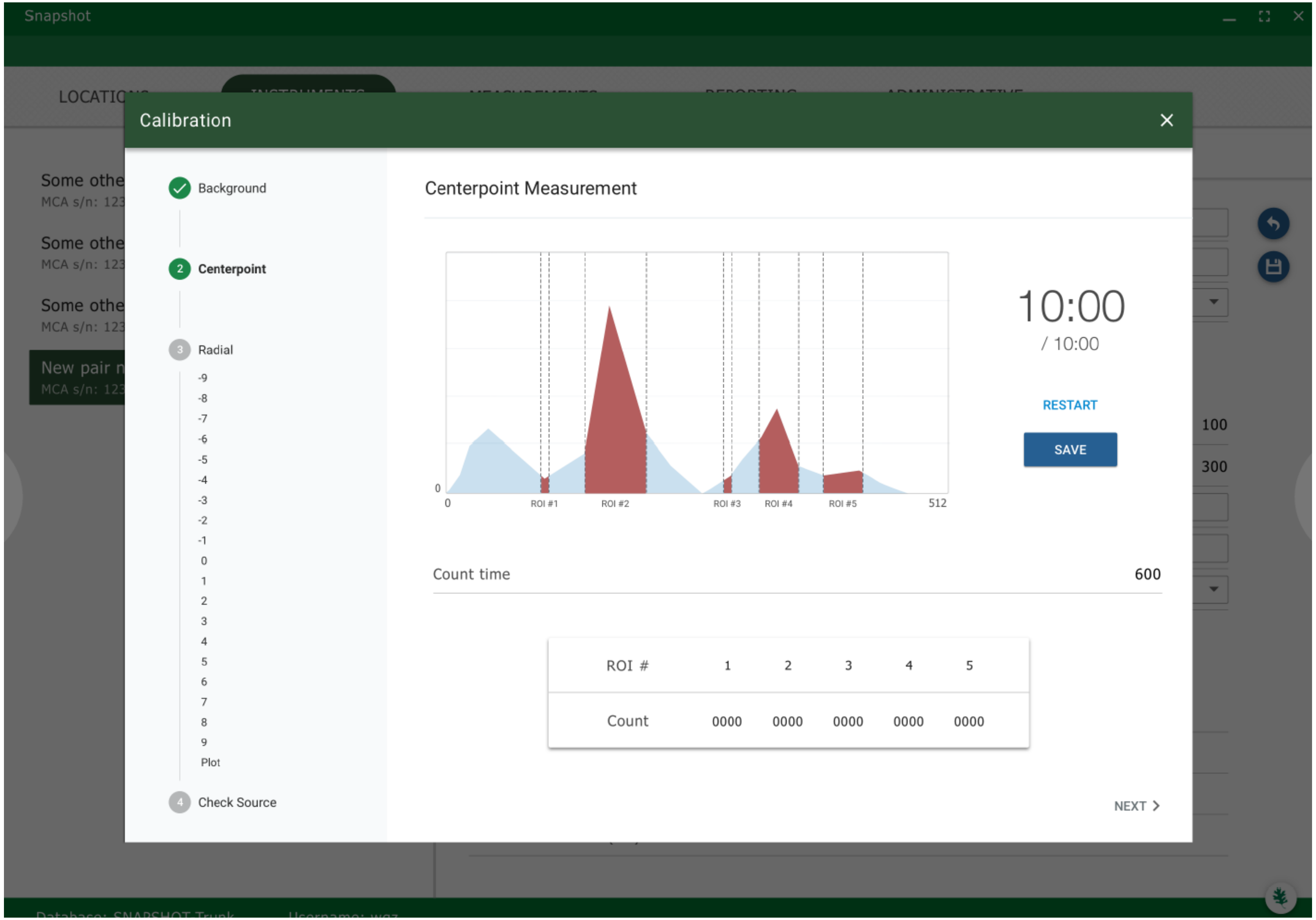
- Setup allows detector/MCA pair to be stored
- Visual Gain Adjustment button provides pop-up window to aid user in setup

Instruments – Calibration



- User can select isotope of interest which reduces number of parameters manually entered for analysis
- Calibrate button leads user through calibration measurements through pop-up

Instruments – Calibration – Measurement Pop-up



- Pop-up guides user through calibration process
- Spectral data is automatically saved eliminating the need for 3rd party data acquisition and manual entry of ROI data

SNAPSHOT - Future

- The next major feature is the development of a compatible data acquisition capability including a SNAPSHOT Field Application
- Initial development will ensure compatibility with existing hardware including the Ortec DigiDART and the GBS Elektroniks MCA-527

17.19 – Technical Support for DNFSB Recommendation 2007-1 and NNSA NDA Technology Infrastructure Program

POC: Douglas G. Bowen (ORNL)

Background – DNFSB 2007-1 *Safety-Related In Situ NDA of Radioactive Materials (1)*

- Defense Nuclear Facilities Safety Board (DNFSB) expressed their concerns about the use of *in situ* NDA techniques (measurement of signature emissions from a specific isotope of interest)
  - large uncertainties and inaccuracies have occurred in estimating the type and quantity of radioactive material using *in situ* NDA
    - include incorrect assumptions about shielding and the spatial distribution of radioactive material – as well as poor measuring techniques
  - measurement errors, in turn, lead to
    - potential criticality accident conditions
    - unexpected radiation exposure to workers
    - underestimation of radioactive material available for release in accident scenarios

Background – DNFSB 2007-1 *Safety-Related In Situ NDA of Radioactive Materials (2)*

- Lack of Standardization
  - DOE has not established programmatic requirements for NDA even though the method is heavily relied upon for safety throughout the DOE complex
  - NDA is a key capability for many DOE activities, e.g., NCS limit compliance, monitoring of fissionable material holdup, etc.
  - The capability to perform accurate measurements and use the results to determine compliance with nuclear safety limits is essential to facility missions
- Lack of R&D Activities
  - R&D efforts for NDA have historically focused on Material Control and Accountability (MC&A) and nuclear material safeguards and advances in these areas peripherally benefitted *in situ* NDA measurement capabilities
    - Current R&D efforts appear to hold little promise for addressing needed improvements for in situ NDA measurements
      - e.g., development of instrumentation and measurement techniques is needed to reduce overall measurement uncertainty
- Lack of design requirements for new facilities
  - Design facilities to minimize holdup or to facilitate effective NDA measurements

NDA Technical Support Group

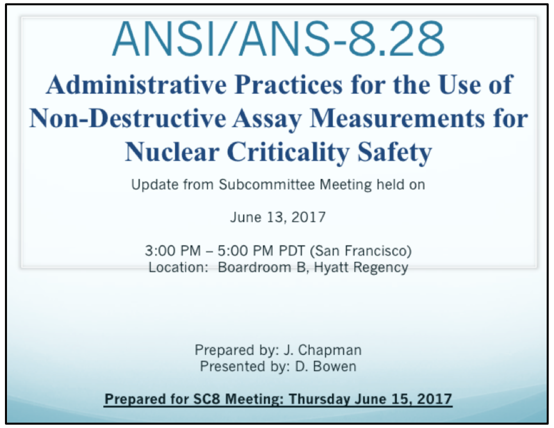
- On October 24, 2007, the Department of Energy (DOE) accepted DNFSB Recommendation 2007-1
- In DOE's Implementation Plan for the Recommendation, DOE stated:
  - TSG was formed in response to DNFSB Recommendation 2007-1 and is comprised of personnel from DOE staff and contractors.
  - The TSG staff will have expertise in NDA holdup measurements and NCS
  - The support group will assist the Department in the specific areas of concern highlighted in Recommendation 2007-1
  - The TSG Membership

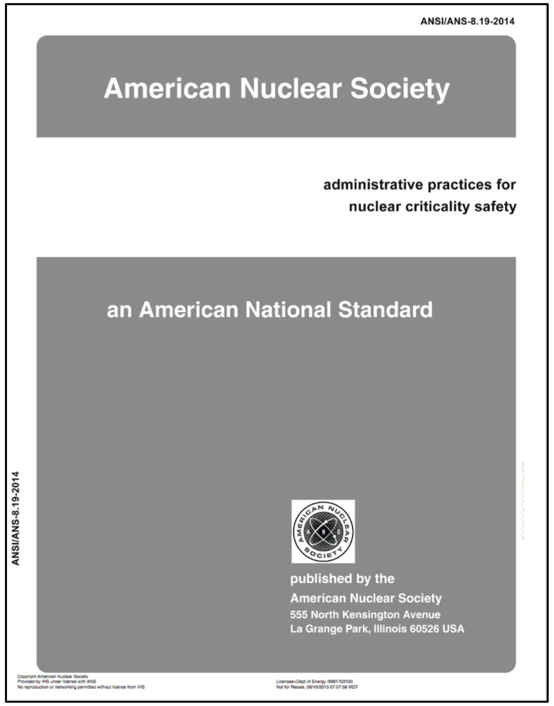
Cynthia Gunn (Y12)	Jeff Chapman (ORNL)
Doug Bowen (ORNL)	Dave Dolin (SRS)
Tom Sampson (Consultant)	Cory Hudson (Y12)

  - The primary function of the TSG is to provide operational and technical expertise to the DOE (EM and NNSA) through the Chief of Nuclear Safety (CNS)

ANSI/ANS-8.28-20XX – Administrative Practices for the Use of NDA Measurements for NCS

- Administrative practices for the conduct of NDA for NCS purposes and includes (modeled after ANS-8.19)
  - Roles and responsibilities
  - Training
  - NCS process evaluation
  - Material control and procedures
- Applies to NDA measurements of fissionable material for NCS purposes, e.g., limit compliance
  - FM in-situ, e.g., held up material in duct work, tanks, etc.
  - FM in containers
  - Parameters such as mass, concentration, and isotopics
- ANSI/ANS-8.28-20XX draft has been through the first round of the ANS-8 subcommittee balloting process (March 2019)





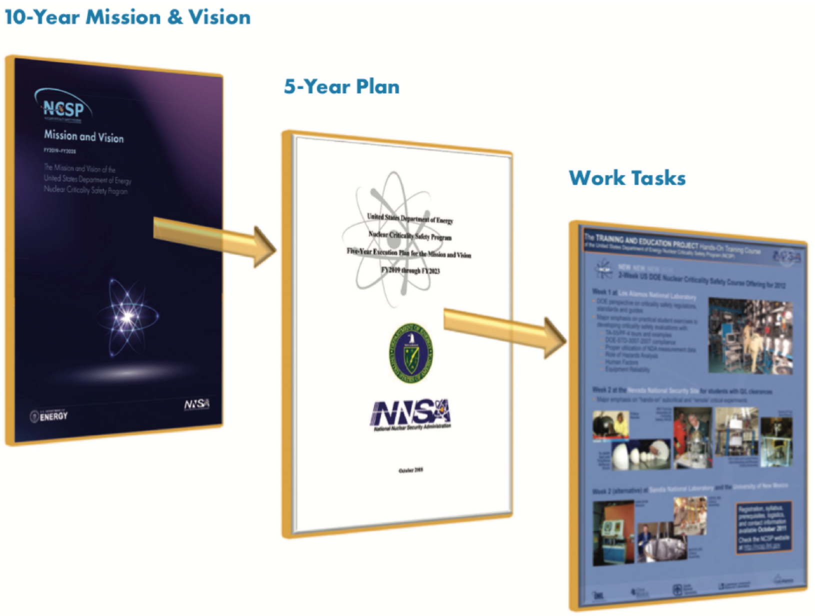
TSG Activities – DOE NDA Standard for Nuclear Criticality Safety

- Effective *in-situ* Non-Destructive Assay Holdup Measurements in Support of NCS
  - **Goal**: *In situ* measurements of radioactive materials are performed to monitor and detect the hold-up of fissile material in process ventilation, piping, and processes over time that could eventually develop into significant NCS concerns and potentially result in a worker safety risk
  - DOE NDA NCS standard will be the implementation method of ANSI/ANS-8.28
  - Provides requirements and recommendations for implementing and maintaining an effective NDA in situ holdup measurement program in support of NCS at DOE nonreactor nuclear facilities
  - Includes administrative and technical guidance related to program implementation and maintenance and includes training and qualification topics
- Provides site/facility operators with the requirements for meeting DOE requirements found in DOE O 420.1C, Ch. III, Sect. 3.e):
  - "Facilities that conduct operations using fissionable material in a form that could inadvertently accumulate in significant quantities must include a program and procedures for detecting and characterizing accumulations."

TSG Activities – NDA Technical Infrastructure Program for NCS

- NDA Technical Infrastructure Program Mission & Vision (M&V)
  - Modeled after the DOE/NNSA Nuclear Criticality Safety Program (NCSP)
  - Arranged into technical program elements with attributes and goals
  - Updated every 5 years; valid for 10 years.
- NDA TIP 5-Year Plan
  - Provides tasks, milestones, and funding to take action on completing the M&V attributes and goals for the program elements

Based on the structure of the NCSP



DOE NDA Program – Mission & Vision

- The six broad program technical elements based in part on the DNFSB 2007-1 recommendations are:
  1. Methods and Data
  2. Hardware and Detection Systems (HDS)
  3. Training and Education
  4. Technical Support Expertise
  5. Benchmark Experiments and Calibration Standards
  6. Information Preservation and Dissemination

This has been delayed to allow for alignment with NDA workshop technical categories, programmatic, and technical gaps.

2.2.3. NDA HDS Attributes and Goals

The NDA HDS program element will have the attributes and goals towards achieving its vision as shown in the tables to follow. Budget priority rankings are based on the current and projected budgets during the next 5 and 10 years. Color coding for the priority rankings in these tables is shown below.

Color Code	
(red)	High Priority
(yellow)	Medium Priority
(green)	Low Priority
(blue)	S T R E T C H

NDA Hardware and Detection Systems – Budget and Technical Priority Rankings

Attributes	Goals	5y	10y
		Budget Priority Technical Priority	
NDA equipment being used enables measurements to meet data requirements of the end user	Confirm that: • Equipment being used will ensure that measurement results meet customer requirements • Equipment being used is controlled to avoid tampering and that there is adequate equipment maintenance capability.		
Equipment used for NDA measurements complies with applicable QA and SQA requirements	Determine if each site has a process for verifying and maintaining configuration control on NDA software • Confirm that software being used is developed and maintained under a documented and accepted SQA plan • Confirm that each site has a process for reconfirming QA and SQA requirements and customer requirements following equipment repair or instrument replacement		
NDA organizations use equipment that is appropriate to meet end user needs and the equipment is calibrated to confirm instrument output compared to reference standards or from detector models	Determine if sites have process to determine when current equipment is antiquated and to identify, procure, and qualify new equipment • Confirm during site reviews that instrument calibrations are documented, current, and demonstrate instrument output compared to those from reference standards or modeled parameters		
NDA measurements account for, and/or correct for, and quantify measurement uncertainties appropriate to the measurement	Ensure that measurement uncertainty contributions are identified, quantified, and reported. • Determine if uncertainties (systematic, random, total) are well understood and reported with measurement results • Confirm that procedures clearly show how to		

NDA 5-Year Plan – Example

Task Descriptions and Deliverables for Each Technical Program Element

2.1.2.3 Oak Ridge National Laboratory (ORNL)

Task Name	Task Title
ORNL-AM1	Radiation Safety Information Computational Center (RSICC)
Budget	**Collaborators**
$325K	None

RSICC ongoing approved task to collect, update, package, and distribute software and associated nuclear data libraries (i.e., SCALE, MCNP, VIM, and COG and nuclear data processing (i.e., NJOY, AMPX and SAMMY) to the NCS community. The NCS community includes: DOE and NNSA M&O NCS staff, e.g., LANL, LLNL, SNL, SRNS, etc., DOE-EM M&O NCS staff, e.g., PGDP, PORTS, SRNL, etc. This does not include NRC-regulated NCS staff, M&O subcontractors, and independent consultants. University students in Nuclear Engineering programs performing NCS analysis is also included. Also, test and disseminate processed nuclear data associated with the software.

Task Name	Task Title
ORNL-AM2	SCALE/KENO/TSUNAMI Maintenance and Support/Cross-Section and Generation/Modernization
Budget	**Collaborators**
$1,200K	IRSN (IRSN-AM1, IRSN-AM3)

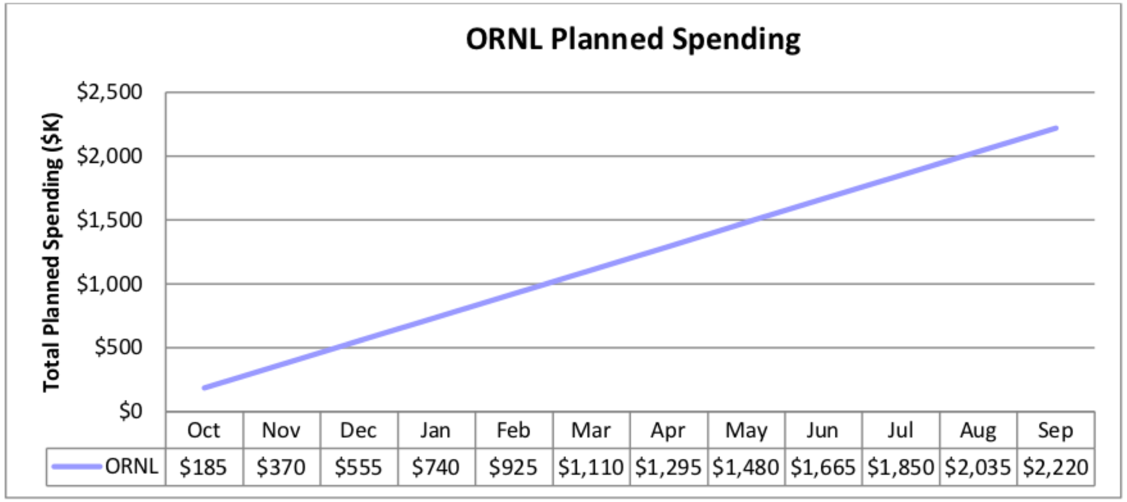
Ongoing, approved task to provide SCALE/KENO/TSUNAMI maintenance and user support for performing Nuclear Criticality Safety (NCS) calculations with the SCALE package. Work tasks include: sustaining and continually improving SCALE NCS features through user-driven enhancements, software quality assurance (SQA) and V&V; assuring adaptability to various computing platforms and compilers; providing improved user interfaces and user documentation consistent with modern engineering software; supporting responsive communication to SCALE criticality safety users through SCALE Newsletters, email notices, and updates on the SCALE website. The task also includes support for modernizing the software infrastructure and capabilities to improve quality and reliability and to ensure long-term sustainability of the NCS capabilities.

Task Name	Task Title
ORNL-AM3	AMPX Maintenance and Modernization
Budget	**Collaborators**
$270K	IRSN (IRSN-AM9)

Ongoing, approved task to develop and maintain the AMPX nuclear data processing code system to provide cross-section and covariance data libraries for NCS radiation transport software such as SCALE. In addition, the task includes additional effort to implement new software enhancements needed to improve the quality and reliability of the nuclear data libraries that are produced by AMPX. The overall development and maintenance work effort will ensure the AMPX software is up-to-date and in conformance with ENDF/B formats and procedures. Moreover, the development and enhancements to the AMPX software will enable improved nuclear data processing capabilities needed to provide reliable nuclear data libraries to support radiation transport methods development and analyses.

Budget

Table 2.1-7 ORNL AM Planned Spending (FY2019)



ORNL AM Milestones:

Milestones

Occurs all 4 Quarters

- Continue distribution of available and newly packaged software to the NCS community requesters (at no direct cost to them) and provide distribution totals quarterly. (AM1)
- Provide status reports on ORNL participation in US and International Analytical Methods collaborations and provide brief trip summary report to NCSP Manager on items of NCSP interest. (AM2, AM3)
- Provide status on ORNL AM activities in NCSP Quarterly Progress Reports. (AM1, AM2, AM3, AM6, AM9, AM10, AM11, AM13, AM14, AM15, AM16)

Quarter 2

- Issue an annual SCALE maintenance report to the NCSP Manager. (AM2)

Quarter 4

- Publish annual newsletter to users to communicate software updates, user notices, generic technical advice, and training course announcements. (AM2)
- Document AMPX modernization and technical support for SCALE CE, multigroup, and covariance libraries and report status annually to the NCSP Manager. (AM3)

EOC – for out-year peaks and dips in budget plots:
ORNL's funding will decrease slightly over the period FY19-22 but will increase in FY23 due to a slight increase in SCALE maintenance funding in FY23.

Conclusion/Path Forward

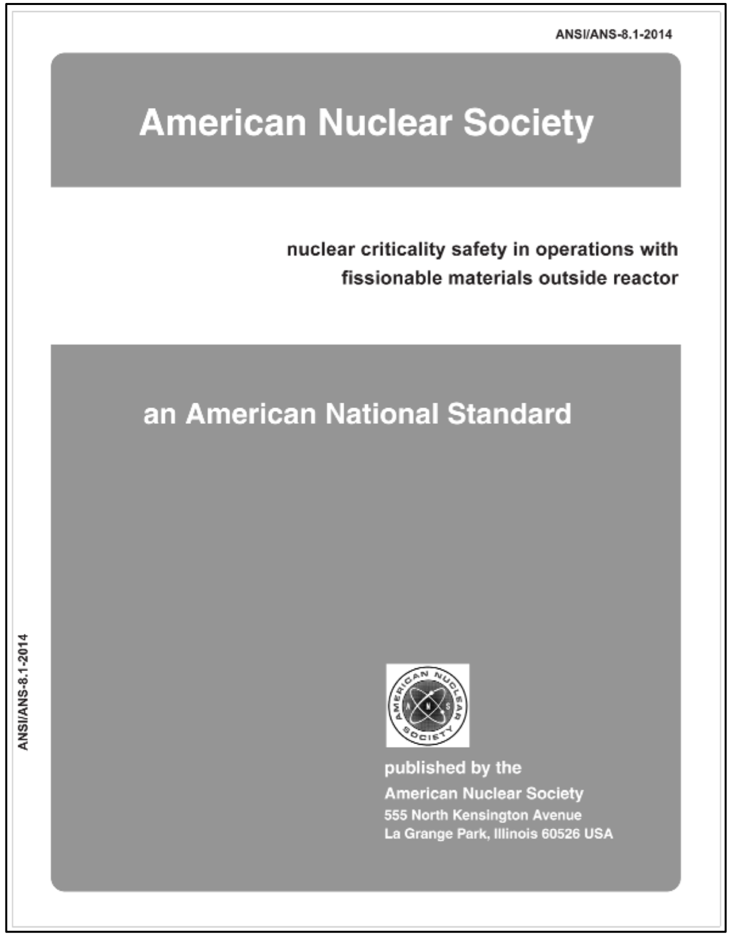
- The TSG needs to continue efforts on the following to continue efforts on the implementation plan for 2007-1 DNFSB Recommendation
  - Development of the NDA Technology Infrastructure Program for NCS
    - Mission and Vision and 5-year plans – due by the end of this fiscal year for review
  - Completion of the ANSI/ANS-8.28-20XX standard
  - DOE NDA standard for NCS to implement the requirements of ANSI/ANS-8.28-20XX
- These products will help to ensure consistency of NDA practices at DOE/NNSA sites for the sake of Nuclear Criticality Safety
- There are currently issues with re-invigorating the Technical Support Group
  - Dave Dolin, TSG chair, is working on TSG workload, charter, and a new schedule for the completion of ongoing tasks
  - This group should also be working to investigate hold up issues at DOE and NRC-regulated facilities to propagate lessons-learned
  - The DOE/NNSA NCSP will be funding the TSG until a new NDA program for NCS is approved

18.03 – Verification of Subcritical Limits in ANSI/ANS-8.1-2014

POC: Douglas G. Bowen (ORNL)

Technical Objective

- Verify the subcritical limits (SCLs) in the ANSI/ANS-8.1-2014 (ANS-8.1) standard provide sufficient margins of safety for safety basis and nuclear criticality safety (NCS) purposes
- The bases for these limits are difficult to ascertain – the limits are more than 30 years old
  - Very old transport codes and neutron cross sections (ENDF/B-IV)
  - Limits based on a combination of experimental data and code computations
  - ^{233}U nuclear data and cross sections are known to have deficiencies
  - Computational and cross sectional bias and bias uncertainties for each SCL are not well understood
    - NRC will not endorse some of the subcritical limits in the standard
    - Computational method validation has not been done in a traditional sense



Drivers

- The NRC has published Draft Reg. Guide 3.71, "Nuclear Criticality Safety Standards for Nuclear Materials Outside Reactor Cores," in 2018 to provide to the NCS community for comment
  - The draft provides a section titled, "Nuclear Criticality Standards Endorsed by the NRC with Clarifications or Exceptions," where it states there is an error in the $^{239}Pu(NO_3)_4$ fissile concentration limit, listed in Table 1 of ANS-8.1
  - Other SCL limit values may also be in question
- There currently is no safety issue with this particular SCL; however, the other SCLs in the standard <u>should</u> be verified using modern neutron transport codes and cross sections

Background (1)

- Informal verification computations have been performed by the ANS-8.1 working group to ensure there were no significant safety issues with the $^{239}Pu(NO_3)_4$ fissile concentration limit
- The recently approved revision project for this standard proposes adding new SCLs for uranium and uranium compounds (<20 wt. % ^{235}U enrichment)
  - The revision scope does not include verification of all the currently available SCLs
- Even if the new revision to ANS-8.1 reconsidered the current SCLs that are currently in the standard, the standard revision is likely to take 5-10 years, based on previous revision experience.
- This effort can enhance the current revision to ANS-8.1 by providing new, vetted, SCL values that the working group can consider for inclusion in the current revision

Subcritical Limits Available in ANSI/ANS-8.1-2014

- Single parameter, subcritical limits
  - Table 1 – Uniform aqueous solutions of fissile nuclides (^{233}U, ^{239}Pu, ^{235}U)
  - Table 2 – ^{235}U enrichment subcritical limits for uranium mixed homogeneously with water
  - Table 3 – Single-parameter subcritical limits for metal units
  - Table 4/5 – Single-parameter subcritical limits for oxides containing no more than 1.5% water by weight at full and half density
- Multi-parameter subcritical limits
  - Figures 1-5 – Subcritical mass, cylinder diameter, slab thickness, volume, and areal density limits for uranium-water lattices
  - Table 6 – Subcritical limits for uniform aqueous solutions of low-enriched uranium
  - Table 7 – Subcritical limits for uniform aqueous solutions of $Pu(NO_3)_4$ containing ^{240}Pu

Table 1 – Single-parameter subcritical limits for uniform aqueous solutions of fissile nuclides

Parameter	Subcritical limit for fissile solute				
	$^{233}UO_2F_2$ [15]	$^{233}UO_2(NO_3)_2$ [15]	$^{235}UO_2F_2$ [16]	$^{235}UO_2(NO_3)_2$ [16]	$^{239}Pu(NO_3)_4$ [16]
Mass of fissile nuclide (kg)	0.54	0.55	0.76	0.78	0.48
Diameter of cylinder of solution (cm)	10.5	11.7	13.7	14.4	15.4
Thickness of slab of solution (cm)	2.5	3.1	4.4	4.9	5.5
Volume of solution (L)	2.8	3.6	5.5	6.2	7.3
Concentration of fissile nuclide (g/L)	10.8	10.8	11.6	11.6	7.3
Atomic ratio of hydrogen to fissile nuclide[1)]	2390	2390	2250	2250	3630
Areal density of fissile nuclide (g/cm^2)	0.35	0.35	0.40	0.40	0.25

[1)] Lower limit.

Table 2 – ^{235}U enrichment subcritical limits for uranium mixed homogeneously with water[1)]

Compound	Subcritical Limits (wt% ^{235}U)
Uranium metal	0.93
UO_2, U_3O_8, or UO_3[2)]	0.96
$UO_2(NO_3)_2$	1.96

[1)] See Ref. [16].
[2)] With water content limited to 1.5%, the enrichment limit is increased to 3.2% ^{235}U [16].

Table 3 – Single-parameter subcritical limits for metal units

Parameter	Subcritical limits for		
	^{233}U [15]	^{235}U [16]	^{239}Pu [17]
Mass of fissile nuclide (kg)	6.0	20.1	5.0
Cylinder diameter (cm)	4.5	7.3	4.4
Slab thickness (cm)	0.38	1.3	0.65
Uranium enrichment (wt% ^{235}U)	–	5.0	–
Maximum density for which mass and dimension limits are valid (g/cm^3)	18.65	18.81	19.82

Table 4 – Single-parameter subcritical limits for oxides containing no more than 1.5% water by weight at full density

Parameter	$^{233}UO_2$ [15]	$^{233}U_3O_8$ [15]	$^{233}UO_3$ [15]	$^{235}UO_2$ [16]	$^{235}U_3O_8$ [16]	$^{235}UO_3$ [16]	$^{239}PuO_2$ [17]
Mass of fissile nuclide (kg)	10.1	13.4	15.2	32.3	44.0	51.2	10.2
Mass of oxide (kg)[1)]	11.7	16.0	18.7	37.2	52.8	62.6	11.5
Cylinder diameter (cm)	7.2	9.0	9.9	11.6	14.6	16.2	7.2
Slab thickness (cm)	0.8	1.1	1.3	2.9	4.0	4.6	1.4
Maximum bulk density for which limits are valid (g/cm^3)[2)]	$\frac{9.38}{1-0.085(1.5-w)}$	$\frac{7.36}{1-0.065(1.5-w)}$	$\frac{6.56}{1-0.056(1.5-w)}$	$\frac{9.44}{1-0.086(1.5-w)}$	$\frac{7.41}{1-0.065(1.5-w)}$	$\frac{6.60}{1-0.057(1.5-w)}$	$\frac{9.92}{1-0.091(1.5-w)}$

[1)] These values include the mass of any associated moisture up to the limiting value of 1.5% by weight.
[2)] w represents the quantity of water, in wt % in the oxide

Table 5 – Single-parameter subcritical limits for oxides containing no more than 1.5% water by weight at no more than half density[1)]

Parameter	$^{233}UO_2$ [15]	$^{233}U_3O_8$ [15]	$^{233}UO_3$ [15]	$^{235}UO_2$ [16]	$^{235}U_3O_8$ [16]	$^{235}UO_3$ [16]	$^{239}PuO_2$ [17]
Mass of fissile nuclide (kg)	23.4	30.5	34.7	88	122	142	27
Mass of oxide (kg)[2)]	27.0	36.6	42.4	102	146	174	30
Cylinder diameter (cm)	11.9	14.8	16.3	20.4	26.0	28.8	12.6
Slab thickness (cm)	1.6	2.2	2.6	5.8	8.0	9.3	2.8

[1)] These are half the maximum bulk densities of Table 4.
[2)] These values include the mass of any associated moisture up to the limiting value of 1.5% by weight.

Tasks, Deliverables, & Funding

Subtask	2018	2019
Subtask 1 – Calculate Single Parameter SCLs • Develop computational methodology, prepare input files, and develop a methodology to summarize computational output data. • Calculate new SCLs for uniform aqueous solutions of fissile nuclides • Calculate new SCLs for ^{235}U enrichment subcritical limits for uranium mixed homogeneously with water • Calculate new SCLs for metal units • Calculate new SCLs for oxides containing no more than 1.5 wt. % water by weight at full & half density • Calculate new SCLs for uranium-water lattices	\$100k	–
Subtask 2 – Calculate Multi-Parameter SCLs • Calculate new SCLs for uniform aqueous solutions of low-enriched uranium," for UO_2F_2 and $UO_2(NO_3)_2$ for fissionable mass, cylinder diameter, slab thickness, volume, and concentration over an enrichment range of 2-10%. • Subcritical limits for uniform aqueous solutions of $Pu(NO_3)_4$ containing ^{240}Pu for ≥5 wt. % ^{240}Pu and ≤1 wt. % ^{241}Pu, ≥15 wt. % ^{240}Pu and ≤6 wt. % ^{241}Pu, and ≥25 wt. % ^{240}Pu and ≤15 wt. % ^{241}Pu.	–	\$35k
Subtask 3 – Compile new SCL limits and provide a summary report to the NSR&D Manager	–	\$25k
Subtask 4 – Generate a journal article for Nuclear Science and Engineering for community reference.	–	\$50k
TOTAL	\$100k	\$110k

There are currently some delays due to the loss of personnel at ORNL. Calcs are now back in progress.

Subtask 1 milestones are about 60% complete.

Subtask 2-4 milestones are pending.

18.19 – Gamma Imaging for In-Situ Holdup

ORNL POC: Klaus-Peter Ziock

Gamma Imaging for In-Situ Holdup

- The goal of this project is to explore the use of gamma-ray imaging for use in detecting, localizing, and quantifying holdup deposits by using an extant imager at the Y-12 National Security Complex
- To this end, a week-long measurement campaign was conducted in late October of 2018 at a number of sites at Y-12
- The measurements used the ORNL coded-aperture gamma-ray imager (Fig. 1) that is based on a commercially available, mechanically cooled high purity germanium detector

Fig. 1. The ORNL gamma-ray imager.

Gamma Imaging for In-Situ Holdup

- A total of four holdup locations were imaged and a report on the results is in progress (release date TBD)
- To analyze the data, the imager software was modified to allow integration of the ^{235}U activity at the image plane, allowing a quick estimation of the amount of radioisotope that is present
- The primary correction factor that was added was to account for the change in solid angle as a function of material location in the image
- This was only automated for the image plane and does not include depth of field corrections
- Other notable omissions are attenuation of the radiation by the process equipment and self attenuation by the holdup itself
- Within limits, similar to those encountered by the standard generalized holdup method, both of these systematic effects can be corrected and we expect to address these issues in the future

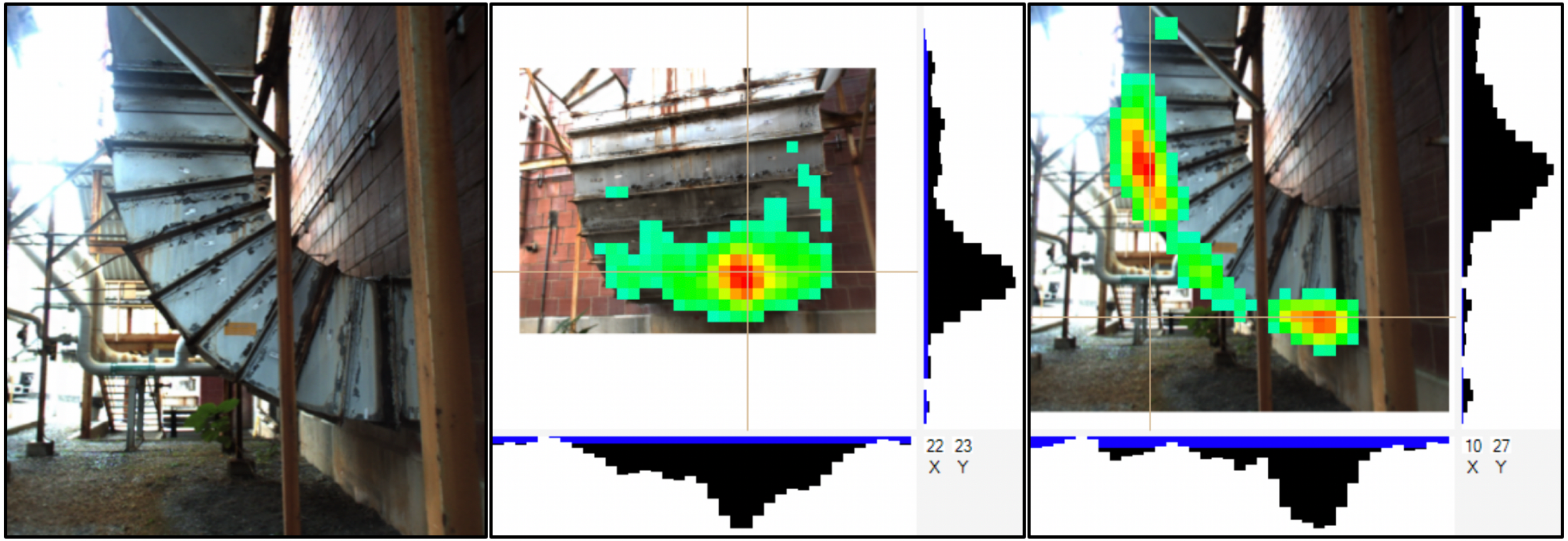


Fig. 2. *Left,* a large "L-duct" was imaged, with the video/gamma overlay results showing the material location within the duct for each of the two views used: *center*, face view, and *right*, side view. the threshold to turn a pixel clear is set to 80 out of 256. The histograms below and to the right of the images (scaled individually) correspond to counts under the horizontal and vertical cursor lines. Zero counts occur at the blue-to-black transition in those histograms. The false color scale is set from maximum to minimum for each image. The gamma-ray imager's field of view in the left-hand images is set to be wider than that of the video camera's field of view, resulting in the white area around the visible light image. The pixel sizes are 11.06 cm and 8.88 cm for the left and right images, respectively.

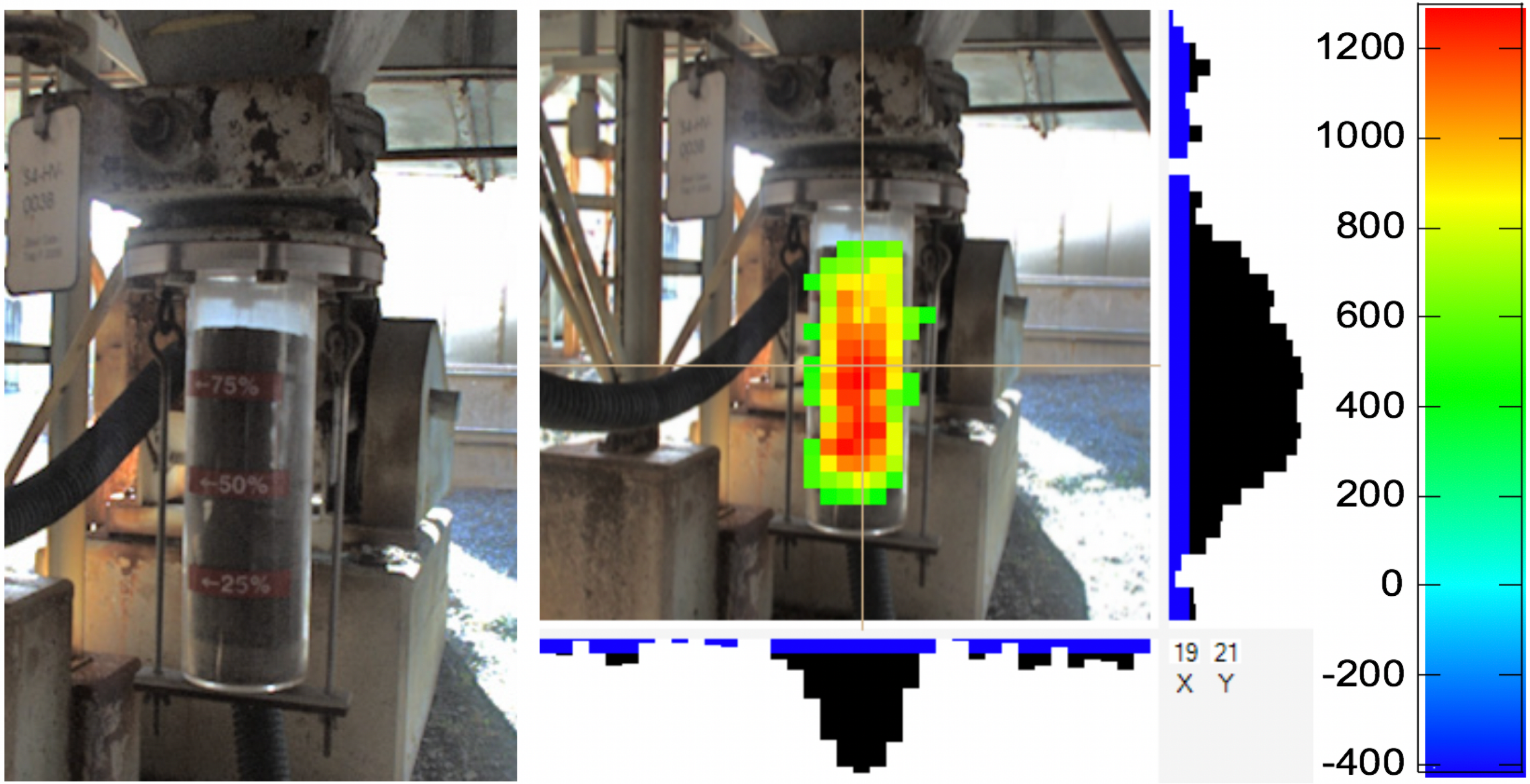


Fig. 3. ***Left*, Collection cup full of material under a HEPA filter housing. *Right*, 10-minute, gamma-ray image of the collector cup with pixels below 50% intensity turned clear to show the location of radioactive material.**

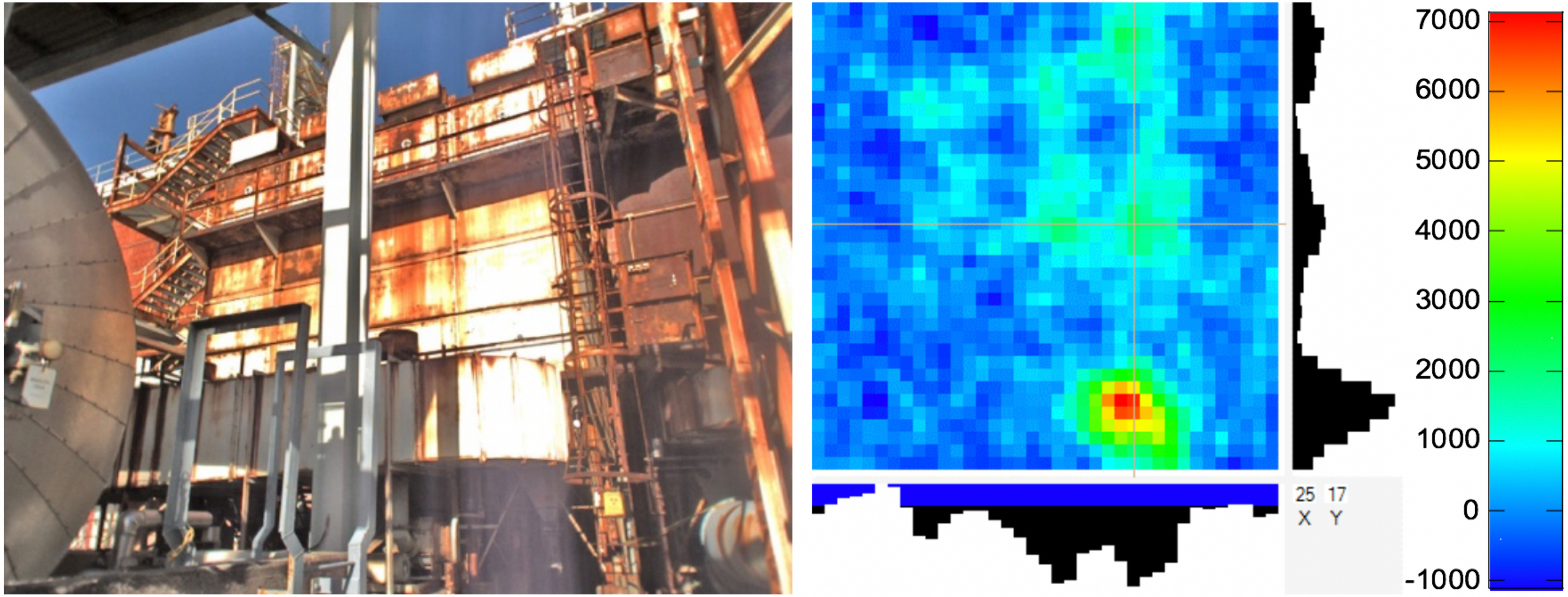


Fig. 4. *Left,* Filter housing structure. *Right,* overnight gamma-ray image of the structure. Diffuse emission is seen in the upper levels of the structure, while the hot spot at the bottom is due to the L-duct (Fig. 2), which is behind the housing.

Fig. 5. Glovebox exhaust duct showing two expansion regions.

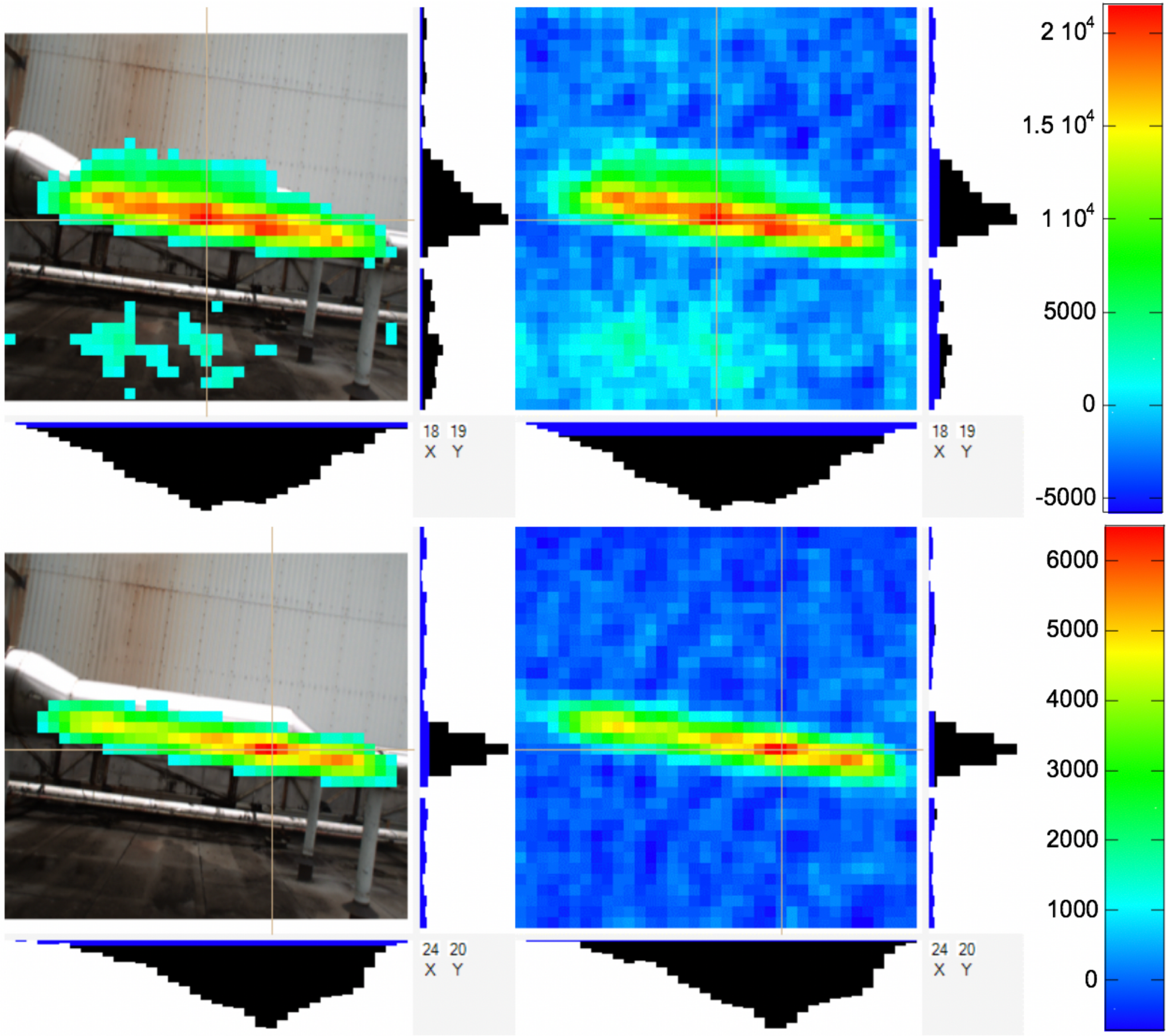


Fig. 5. *Left*, video/gamma overlay images for the Glovebox exhaust duct. *Right*, gamma-ray images for the Glovebox exhaust region. The upper row uses all of the data while the lower row uses only emissions in the 186-keV line. The lower images show the material is restricted to the bottom of the duct and occurs primarily between the two expansion sections. The image is deliberately tilted to handle potential wrap-around effects in the gamma-ray image if the source extends beyond the primary field of view—this did not occur at this location.

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Gamma Imaging for In-Situ Holdup – Path forward

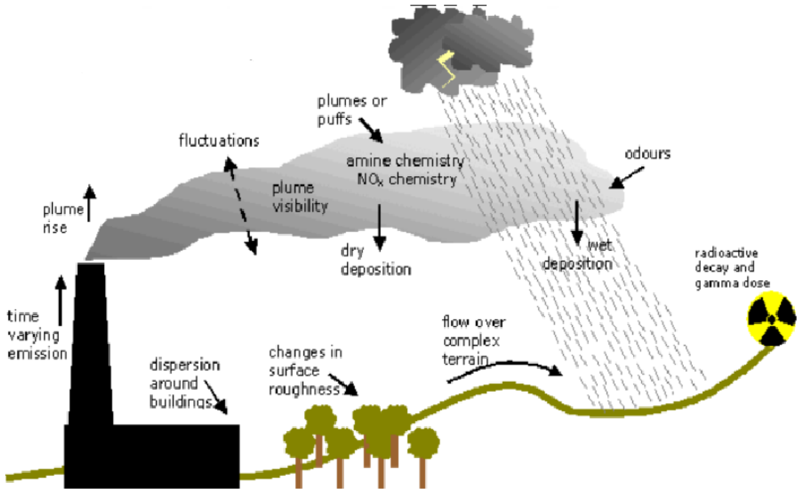
- The statistical limits of the measurements can be calculated based on the counting statistics and image analysis tools developed under another project
- Those results indicate that a few percent statistical uncertainty is possible with site-dependent integrations times from 10 minutes to several hours
- Unfortunately, that earlier work also found that there are systematic limits to the accuracy of the results due to subtle interactions between the mask and detector response functions that are estimated to be ~ ± 5% after solid angle corrections are made
- A generalized correction to fix this, that is valid across the full imager energy band, is beyond the scope of this project, but detailed analysis of the data collected was delayed to pursue a cheaper calibration alternative performed only at the 186-keV line
- An initial attempt with a highly enriched uranium Radiation Signature Training Device was unsuccessful and we are now pursuing acquisition of a ^{166m}Ho source of sufficient activity to perform the calibration

Oak Ridge National Laboratory

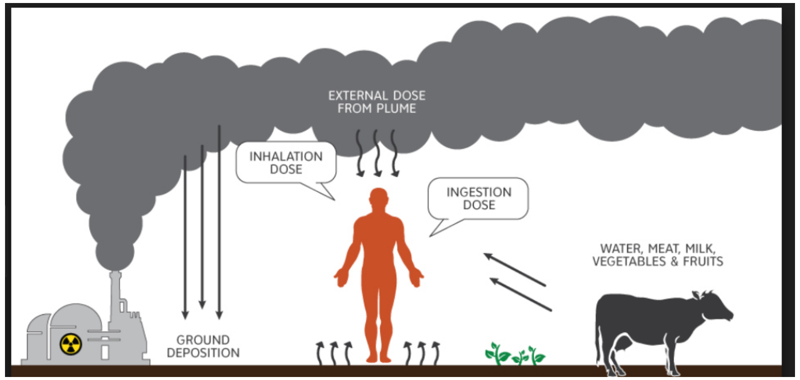
18.20 – Drone Assisted Dispersion and Dose Consequence Modeling using MACCS2

ORNL POCs: Richard Hale (ORNL), Brad Stinson (ORNL), Andrew Duncan (ORNL), Nate Duncan (ORNL), and Nate Bixler (SNL)

Why is this problem important?



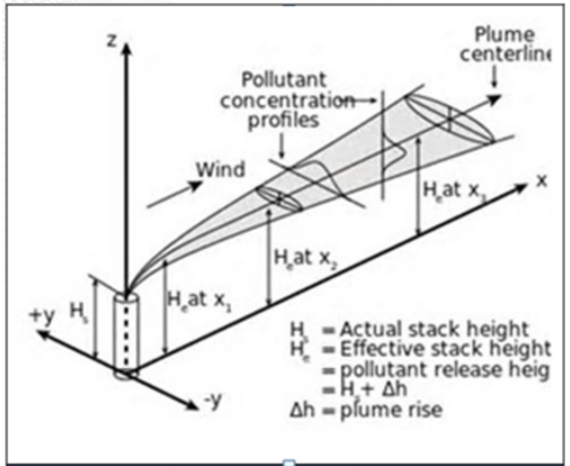
Nuclear facilities must address the public risk of hazardous radiological release to the environment



Calculating the short term and long term health effects and environmental consequences is a complicated problem.

For nuclear facilities public safety ultimately depends on dose consequence

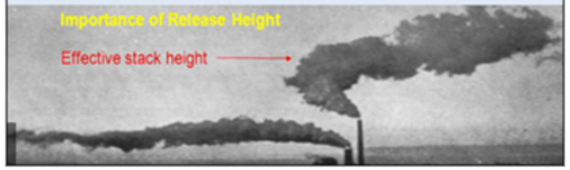
How do we currently estimate this?



A Gaussian plume model for an elevated release is as follows:

$$C(x,y,z) = \frac{Q}{2\pi u_{10}\sigma_z\sigma_y}\exp\left[-\frac{y^2}{2\sigma_y^2}-\frac{(z-H_S)^2}{2\sigma_z^2}\right]$$

where C = the air concentration (Bq/m^3) or its time integral Bq s/m^3
Q = release rate (Bq/s) or total amount released (Bq)
u_{10} = wind speed at 10 m above the ground (m/s)
σ_z = standard deviation of the vertical Gaussian distribution (m)
σ_y = standard deviation of the horizontal Gaussian distribution (m)
H_S = effective release height (m)
x, y, z = rectilinear coordinates of the receptors



Dose and deposition are functions of plume location and extent which can be difficult to estimate using traditional analytic techniques (Briggs equations, etc..)

The path and size of the plume are affected by topography and changing meteorology

Radiological releases are typically not visible and often with no thermal signatures

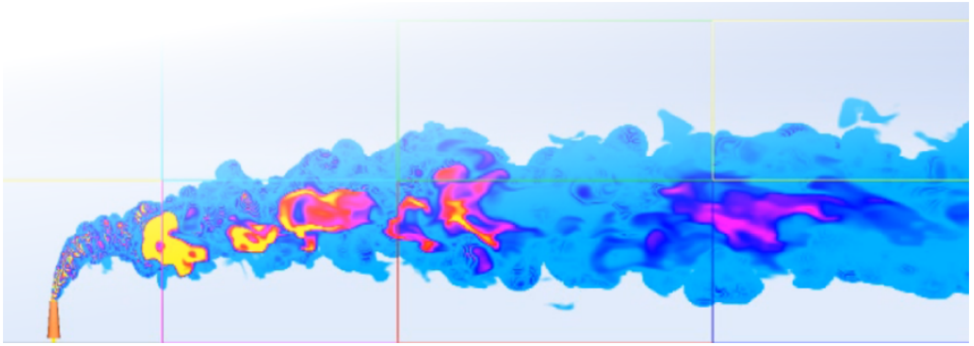
Path of radionuclides is not easily known or discerned

Dose consequence is dependent upon release characteristics and atmospheric dispersion which are difficult to measure

What have we proposed?

Small Radiation detector capable of raw counts/isotope speciation and local/wireless data collection/transmission

Drone carrying radiation detector



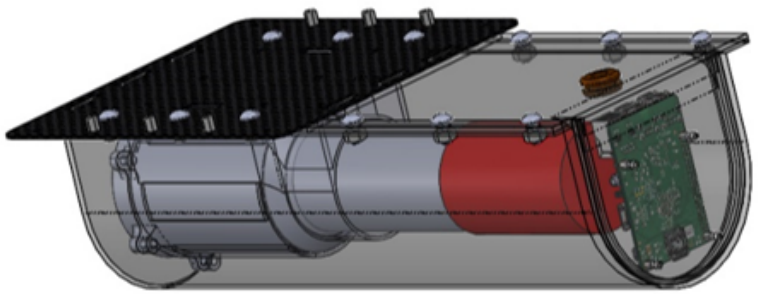
Mapped plume dispersion surrounding ORNL/SNL facilities used for input to MACCS2 dispersion modeling

We proposed development of site specific dispersion modeling with MACCS2 using drone assisted measurements at ORNL and SNL.

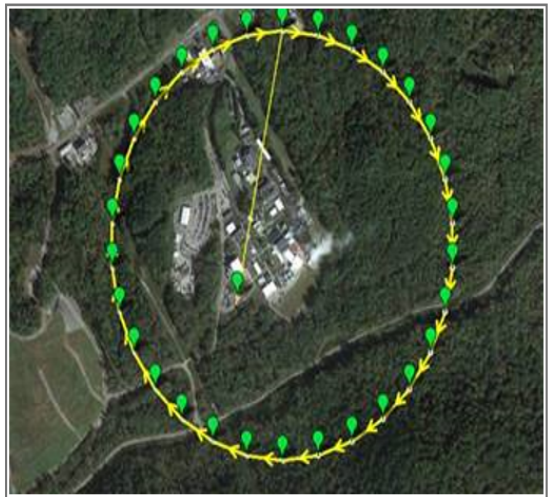
Drone assisted measurement technology and small portable sensors offers a tremendous opportunity to measure essential parameters for dispersion analysis

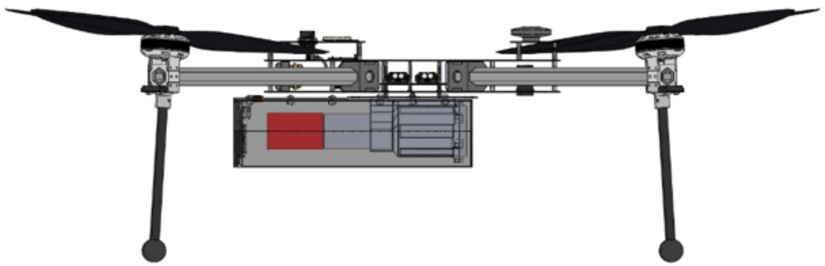
For nuclear facilities public safety ultimately depends on dose consequence

What have we done this year?



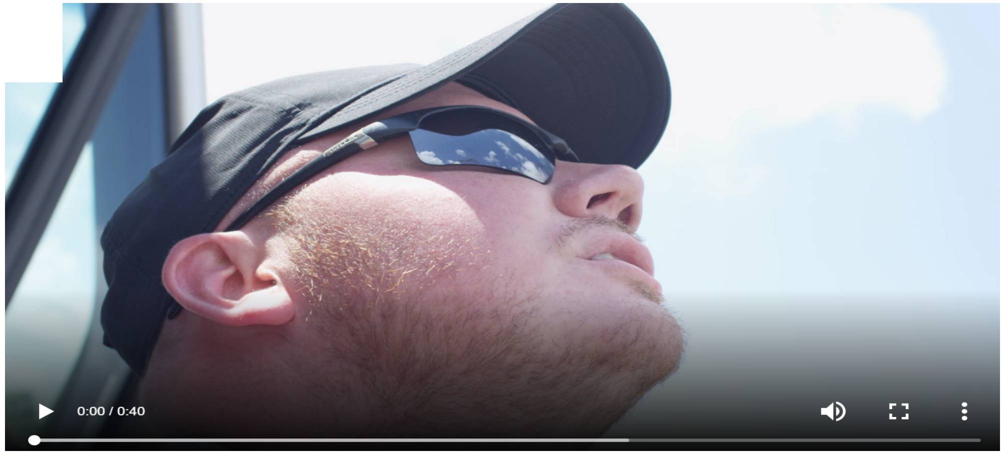
Calibrated Radiation Sensor





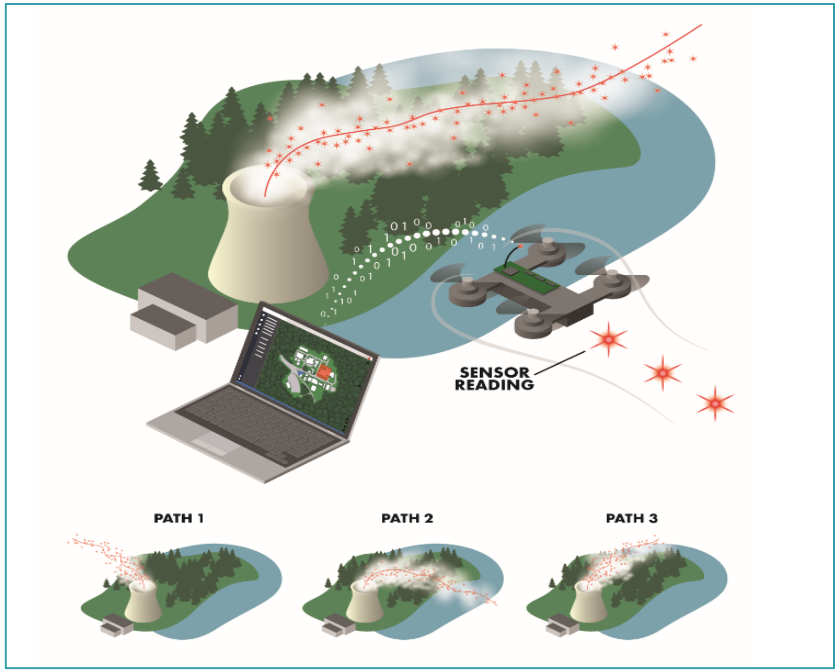
Integrated Radiation Sensor on Drone Platform

Performed Test flights around HFIR in preparation for measurements



In 2018 we established the payload and platform integration and field tested. The field tests successfully showed capability to make *in situ* plume measurements

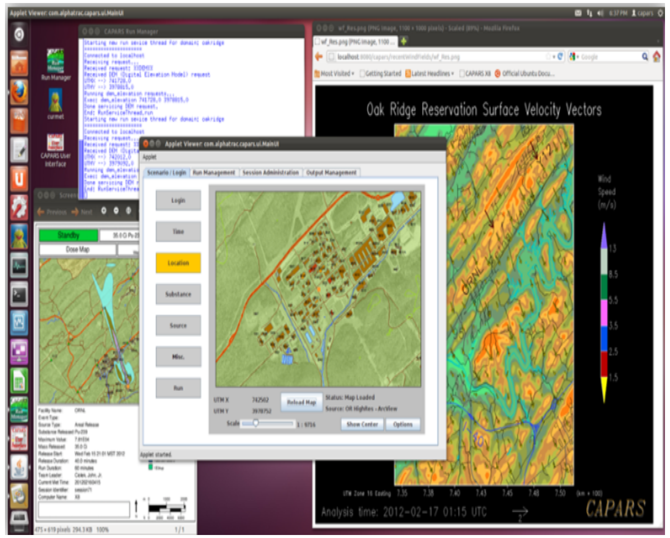
What remains to be done?...Next steps



- 2019 flights will be performed under a range of meteorological conditions to bound the potential range of conditions that would be reflective of any potential release at HFIR.

- Flights profiles estimated using CAPARS (full wind-field model) plume model estimates

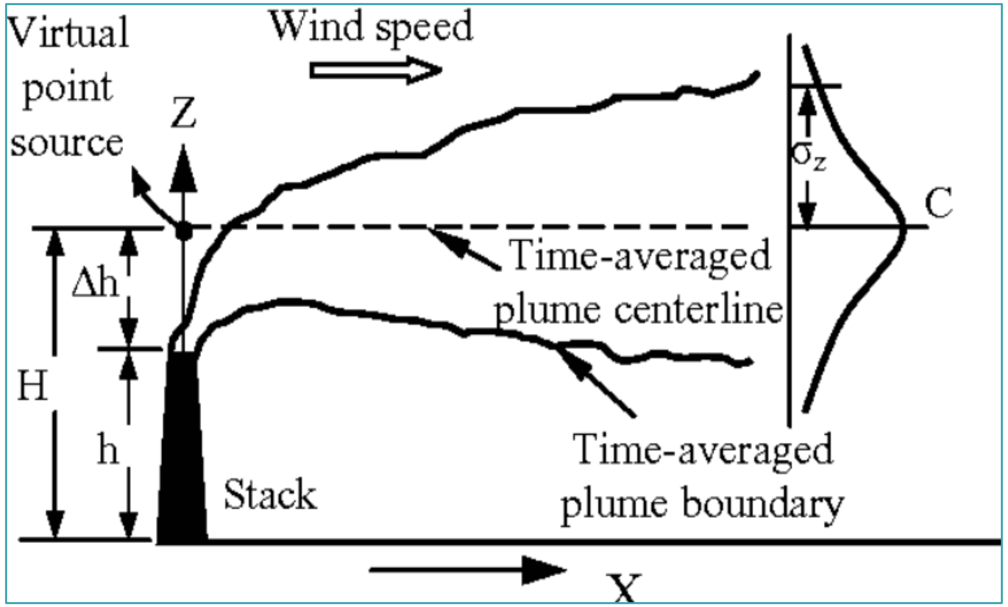
- Flight drone data used to determine actual extent of plume



Plume data will be used to implement a location specific plume model(s) into a new subroutine in MACCS2 that can be called in place of the two existing subroutines.

The equations for the new model(s) will be developed empirically from data measured at a specific site based on drone fly-through measurements.

Drone data will improve site estimates of plume height and plume vertical and lateral dispersion in MACCS2



Acknowledgments

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